Notes from the NOvA WGM February 2007 – chris laughton

1 – As-Built Drawings

Reference to the as-built drawings and sections would be of value – the tunnel was significantly "over-excavated" in places (a combination of drill and blast and Tunnel Boring Machine was used to mine this tunnel section). These drawings will ultimately be needed for contracting purposes anyway – so it might be good to start getting used to them.

2 – Anticipated Ground Conditions

The ground can be troublesome, but for the NuMI Tunnels and Halls contract the methods and means employed in the Scales Shale were pretty well matched to the conditions. The Construction Contractor's claims were mainly associated with allegedly adverse conditions or behaviors encountered in the upper bedrock units (Silurian and Brainard). That is not to say that the Scales (or any other ground mass for that matter) is perfect; it has been troublesome at other sites in the region and is highly stressed at this site. (Some minor signs of distress are observed in the sidewalls of the excavation.) Newly excavated rock will require support and the early application of a reinforced shotcrete lining. Given the in-situ stress environment, the use of a minor amount of in-situ instrumentation will be warranted to monitor ground behavior during mining.

3 – Excavation Options

From a rock engineering perspective, there appear to be two relatively low risk options to create new space in this area: either enlarge/widen the existing excavation a modest amount (say 3+ m) or create a new side tunnel. Thoughts on each option are noted below (a schematic of proposed options and layout rules-of-thumb are shown at the end of the notes).

a - Enlarging the Existing Tunnel

A conservative application of empirical design rules* (not recommended for final design but OK for now) would suggest that an enlargement of up to roughly half the excavated span (say 3+ m) could be made without a requirement for any major change in ground supports (potentially the use of a denser pattern of longer bolts and the continued application of a layer of reinforced shotcrete).

(* conservative rock quality and long-term stability requirement for road/rail tunnels)

b – Creating a New Tunnel

Span increments much beyond half a span are certainly also feasible, but may require the use of different/heavier support systems applied around the whole arch perimeter. They may also carry a higher degree of risk associated with the comportment of the arch structure itself. Not to say it can't be done (underground engineers never say it can't be done - from a technical perspective, the bigger the challenge the better.. but there is potentially a significant price to be paid). Spans up to 35 m have been mined successfully in CERN's Molasse which has some rock layers that are significantly weaker and, locally, more highly stressed than the one we have to work with here.

If much more than half a span of new excavation is required to house the detector (e.g. Option 3), the designer may wish to consider mining a new tunnel, perhaps including a small tunnel (similar in section to the Target Hall personnel labyrinth), to connect back to the Access Tunnel, avoid a dead-end and provide thru-flowing ventilation. Such a solution would improve stability (limit the span), potentially reduce the excavation volume and result in a lower-risk, and perhaps a more practical and cost-effective solution.

4 – Underground Cost Estimates

For this kind of "filigree" work, it would be expected that the direct costs of the excavation and support would be dwarfed by other labor and indirect costs associated with the preparatory work and peripheral activities needed to ensure that the work does not impact our permanent installations. If this is true, it is doubtful that there would be such a large cost delta between the excavation options. Elaine, Peter and I had spent some time developing a cost for Option 1 - it seemed to be relatively conservative. To do this, I relied on my experiences as a drill and blast subcontractor and also referenced similar work undertaken at CERN to come-up with manpower, duration and costs for the excavation/support. Elaine and Peter had done a very thorough and detailed job of scoping and costing the additional work items. I haven't seen the basis of estimate for the other options so I do not know the reasons for the seemingly large price deltas. The Lemley team is very competent at such things so I'd have confidence in any numbers they generated – I like to think that the scope that formed their basis-of-estimate is significantly different than ours – bit of a question mark though.

If optimizing costs is critical, it may be worthwhile developing a basic design (perhaps with a local design contractor who has had some recent experience working in this material – there are at least a couple in the immediate area) and a site-specific cost estimate(s) with an industry partner such as Lemley – a good choice, there are other options too. Developing site-specific designs and costs would help establish a strong basis from which to identify the cost-drivers and major sources of risk and support optimization work. As background to this suggestion, I note that any unit pricing ($ per linear, square or cubic meter) associated with groundworks can have a very wide spread. In particular, underground unit pricing can vary by **orders** of magnitude from site to site as a function of key variables such as ground and groundwater water conditions, environmental and site constraints (the main issue here), requirements for permanent people access/egress etc. In benchmarking the Cascades-DUSEL prices to the North American underground marketplace, I find recent unit-priced tunnel quotes ($/m) ranging from around 10k for simple, no-access sewer lines to well in excess of 1M for major people-accessed thoroughfares.

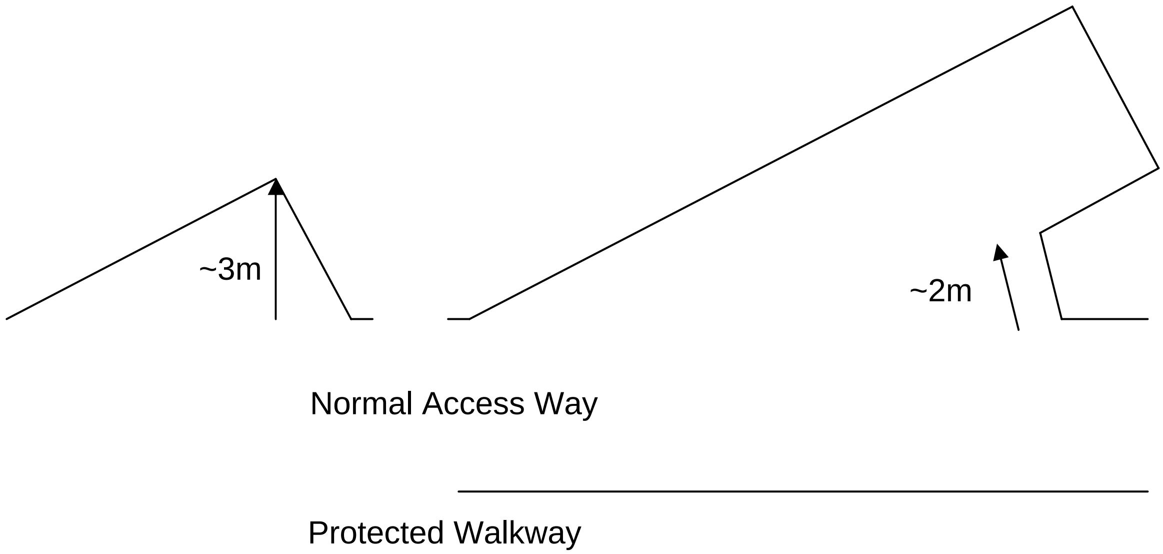
5 – Should you decide to move forwards with any of the excavation options presented, here are a few more thoughts for your perusal:

a) Optimization/Risk Reduction Opportunities. There may be better ways of excavating the rock than the one we initially came up with. Consider contacting local professional associations with expertise in underground excavation (Mining/Civil Engineers, Engineering Geologists, Explosives Engineers, Aggregate Mine Operators..), to explore the advantages of using special blasting techniques/materials and non-explosive options such as a "Roadheader" or "Hydraulic Hammer". There is some precedent locally in the use of these pieces of equipment in similar/same rock units – these methods could have substantial constructability and ES&H advantages over explosives (e.g. less damage to the rock, formation of thinner load-bearing rock pillars, lighter protection for installations, no explosives brought/stored on site, no downtime for securing, detonating and ventilating the works).

b) Consider developing a short Geotechnical Baseline Report to define the ground-related scope for the benefit of bidding contractors - perhaps simply using the NuMI geologic maps and contract texts, referencing NuMI and Illinois-SSC geotechnical papers and exposing the rock in one or two places (short-term "windows") will be adequate for bidding purposes.

c) Consider including a modicum of ground instrumentation and blast vibration monitoring within the contracted scope of work to ensure that deleterious ground movement and vibrations are limited/avoided.

d) The number of contractors who would take this on may not be that large (perhaps small demolition or contract mining companies) and the industry is pretty busy right now. It might be good to identify, make contact with and pre-qualify these specialist contractors a little earlier than normal so that the project is on their "radar screen" for planning/bidding purposes – maybe particularly important if there is a specific time window for construction.



Schematic of the two proposed options…

Suggested rock mechanics-driven rules-of-thumb noted for layout purposes

a) maximum increment in span ~ 3 m
b) minimum pillar width at “nose” ~ 2 m